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Effect of Introgressed Drought QTLs of IR 64 on Physiological traits under Severe Water Stress

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ABSTRACT: *Drastic climatic changes due to anthropogenic activities have resulted in shifts in rainfall patterns and crop experiences frequent drought spells. Rice is most sensitive crop under stress and it can cost grain yield reduction of 65-85% based on drought. Rice is particularly sensitive to drought stress during reproductive growth; even moderate drought stress can slow down carbohydrate synthesis and/or weakens the sink strength at reproductive stages and leads to abortion of fertilized ovaries leading to spikelet fertility. QTLs are reported for yield under stress with high heritability for grain yield and effect on physiological parameters like drought tolerance index, canopy temperature, osmotic adjustment, and leaf water content. Set of BILs introgressed for yield QTLs under stress in the background of IR 64 were evaluated under severe stress for physiological response and effect on grain yield. Higher photosynthetic rate was noticed for high grain yielder BILs as it was positively correlated. Varied expression was noticed for stomatal conductance, transpiration rate among BILs. Chlorophyll content had highly negative correlations with leaf senescence, leaf drying and panicle exertion but, positively correlated with grain yield per plant. Significant effects were noticed for physiological parameters by introgressed QTLs for yield under stress in back ground of IR 64. Optimum values of physiological parameters and high grain yield was expressed by BIL with* DTY2.2 *in the background indicating its effect on several drought related traits.*

Keywords: *Quantitative Trait Loci, Grain yield under stress, physiological parameters, reproductive stage drought tolerance.*

INTRODUCTION

Rice-growing areas span the tropics, subtropics, semi-arid tropics and temperate regions of the world. More than 90% of the world's rice is grown and consumed in Asia, where rice is grown in 135 million ha with an annual production of 516 million tonnes (Roy and Misra, 2002). In India, the area under rice cultivation is 43 m ha with an annual production of 102 million tonnes and an average productivity of 2.37 t ha^{-1}. Drastic climatic changes due to anthropogenic activities have resulted in shifts in rainfall patterns and crop experiences frequent drought spells. Under severe stress, yield reduction in rice is 65-85% compared with that in non-stress conditions (Kumar *et al.* 2008). Rice is particularly sensitive to drought stress during reproductive growth, even under moderate drought stress (Hsiao *et al.*, 1984, O'Toole *et al.*, 1980). In addition, drought stress slows down carbohydrate synthesis and/or weakens the sink strength at reproductive stages and abortion of fertilized ovaries (Rahman *et al.,* 2002). Regarding drought tolerance studies, many works for secondary traits have been reported with little effect on *per se* drought tolerance. Recent studies at IRRI have shown moderate to high heritability of grain yield under drought (Venuprasad *et al.,* 2007; Kumar *et al.,* 2008), thus opening area for direct selection for grain yield instead of secondary traits. Further, direct selection for grain yield under drought has been reported effective (Kumar *et al.,* 2008; Venuprasad *et al.,* 2008) and the feasibility of combining high yield potential with good yield under drought has been demonstrated beyond doubt. The region on chromosome 2 in which q*DTY*2.2 was detected has

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been reported previously to have an effect on drought-related traits other than grain yield, including drought tolerance index, canopy temperature, osmotic adjustment, and leaf water content (Verulkar *et al.,* 2010). Mallikarjuna Swamy *et al.,* 2013 opines that the clustering of a number of physiological traits in the same region suggests its importance for grain yield under severe drought stress. In the present experiment we are aimed at studying effect of yield under stress QTLs on physiological parameters through set of BILs introgressed with QTLs for yield under drought stress and from the tolerant variety Apo into IR64, a major elite variety but, susceptible to drought situations.

MATERIAL AND METHODS

The experiment that was carried out in Paddy Breeding Station, Centre for Plant Breeding and genetics, TNAU, Coimbatore during *Kharif* 2013 under rain out shelter to impose stress experiment (withholding irrigation) without rain intervention. The material for the study consisted of a set of back cross inbred lines of IR64 which were introgressed with QTLs for yield under stress (located on chromosomes 2, 3 and 8), one at a time and combinations of two and three in parental background. The QTLs were originally derived from Apo, an Indica cultivar. F_1s of the cross IR64 and Apo was selfed till F_4 which were phenotyped under severe stress condition at reproductive stage to identify genotype performing with good seed set and grain yield and screened through MAS to derive QTL (yield under stress) positive lines. Recombinant inbred lines of IR64 and Apo in F_4 generation with three QTLs for yield under stress, donated by Apo were used for backcrossing with IR64 to generate BC_1F_1 and were selfed for 2 generations to obtain BC_1F_3. BC_1F_1 were also used for backcrossing to generate BC_2F_1, later selfed till BC_2F_3 and were included in field evaluation. Similarly one BIL (BC_1F_3 of ADT 45) which was introgressed for 3 QTLs *DTY* (2.2+3.1+8.1) was also included in the evaluation. The physiological traits were recorded for selected best and worst performing lines along with the parents and checks.

Field experiments were carried out following the Randomized Complete Block Design with three replications for both control and drought stress conditions. The seeds of BC_1F_3 and BC_2F_3 of IR64 and parents along with check Anna 4 were sown in nursery bed and seedlings were raised. Later single seedling of 17 days old were transplanted on an experimental plot that had two rows of 2.4 m with the spacing of 20 cm between rows and 20 cm between plants within a row per genotype. Gap of 30 cm spacing was maintained between the genotypes. Recommended crop production and protection practices were followed to raise a healthy crop. Regular irrigation was given until 67 days of crop from date of sowing; later crop was denied irrigation for the rest of its duration. Crop was harvested when the grains reached physiological maturity stage in both the experiments.

RECORDING OF PHYSIOLOGICAL TRAITS UNDER STRESS EXPERIMENT

The leaf senescence, leaf rolling, leaf drying and panicle exertion was assessed in each plant after the panicle exertion based on the scores of Standard Evaluation System (IRRI, 1996). Relative water content was estimated by Weatherley (1950) method and expressed in percentage. The basic principle of this technique consists essentially in comparing the water content of leaf tissue when fresh leaf sampled with the fully turgid water content and expressing the results on percentage basis. The midleaf section of about 5 to 10 cm sample is placed in a pre-weighed (oven dried) vial. The leaf samples were placed in a vial slightly longer than the sample with its basal part to the bottom. Vials were immediately placed in an ice box and reached the lab soon. In lab vials were weighed to obtain leaf sample weight (W) after which the sample is immediately hydrated to full turgidity for 4 hours under normal room temperature and light. After 4 hours the samples were taken out of water and well dried of any surface moisture quickly and immediately weighed to obtain full turgid weight (TW). Samples were then oven dried at 80°C for 24 hours and weighed to determine the dry weight (DW). All weighting is done to nearest milligrams. Leaf RWC was calculated using the formula as follows

$$RWC = \frac{(FW - DW)}{(TW - DW)} \times 100$$

Where, FW, TW and DW are fresh, turgid and oven dry weights respectively.

Photosynthetic rate (ì mol CO_2 m^{-2} s^{-1}), stomatal conductance (mol H_2O $m^{-2}s^{-1}$), transpiration rate(TR mmol H_2O $m^{-2}s^{-1}$) and intercellular CO2 concentration (Ci) were measured, using a LI-6400 portable photosynthesis system (Li-Cor Inc., Lincoln, NE), between 10 AM and noon under saturating PPFD of 1500 _mol m–2 s–1. Flow rate was maintained at 200–250 _mol s–1 so that the relative humidity inside the chamber should be similar to ambient conditions.

Measurements were made for 20 s immediately after a stable decrease in CO_2 concentration inside the chamber was achieved.

The penultimate fully expanded leaf on the main stem or on a primary tiller was cut and wrapped in a plastic bag was soaked in water in the refrigerator for 24 h to rehydrate the tissue. The sap was collected by squeezing the leaf sample with the help of a sterile syringe and the osmolality (mmol $kg^{-}1$) of the expressed sap was determined using a vapour pressure osmometer (Vapro, Model 5520 Wescor Inc., Logan, UT, USA). Osmotic potential (wp) was calculated as

$$\Psi\pi = - cRT,$$

Where c is concentration, R is the universal gas constant (0.0832) and T is the temperature in degrees Kelvin (310 ° K).

The following conversion equation was used to compute osmotic potential (in MPa)

$$[(\# \text{ mmol kg}^{-1}) (0.0832) (310)]/10\,000.$$

Chlorophyll content was recorded using a portable chlorophyll meter (Minolta SPAD 502) after imposing drought. The single plant yield was calculated by weighing the cleaned dried grains harvested from the single plant and expressed in grams. Observed data was analysed for statistical significance and correlation studies were carried out to study the association among physiological traits and with grain yield.

RESULTS AND DISCUSSION

Evaluation of Yield and Physiological Parameters under Severe Moisture Stress Condition

Mean value comparison of physiological traits with grain yield for selected individuals under stress condition is depicted in Table 1. There was a significant difference for all the traits observed. Significant differences indicate the level of influence of water stress on various physiological parameters. Higher photosynthetic rate was noticed among better performers than susceptible ones which appreciate the report of Chen *et al*. (1995) who observed elevating photosynthetic rate is beneficial to dry matter production and yield. The BIL CB13-900-C-2-23 possessing *DTY*2.2 recorded higher grain yield also recorded highest photosynthetic rate among other BILs and checks (Fig. 1). Similarly, lowest grain yield and lesser photosynthetic rate was recorded by *DTY*2.2 QTL possessing BIL. Cao *et al*. (2001) reported that photosynthetic rate among rice varieties were significant and the net photosynthetic rate as a selection parameter for drought resistant genotypes. Least photosynthetic rate was recorded by ADT 45 followed by IR 64 while Anna 4 recorded moderate photosynthetic rate value. However moderate to slightly higher values were recorded by 3 QTL combined lines. Least stomatal conductance was recorded by Anna 4 and some of the BILs, ADT 45, IR 64 and Apo recorded moderate values, but moderate grain yielder CB13-900-C-2-17 recorded highest conductance values and correspondingly higher transpiration rate and inter cellular carbon. Mallikarjuna Swamy *et al.,* 2013 reports that +QTL lines showed cooler canopy temperature and greater stomatal conductance than -QTL lines and IR64 under the most severe drought stress, but not under mild drought stress or non-stress conditions. Martinez *et al*. (2007) also pointed out that higher stomatal conductance may be an enhanced adaptation of plants to drought environments. Araus *et al*. (2002) reported that higher yielding genotypes under drought had greater stomatal conductance and transpiration rate. Intercellular Carbon concentration was recorded for the genotypes and ADT 45 recorded highest Ci value and Ci/Ca ratio as it also showed higher conductance, but photo synthetic rate was lesser in ADT 45 which shows the influence of stress on internal mechanism of plant. Among BILs which recorded lower conductance also recorded lower Ci values. Apo recorded lowest Ci value and lowest Ci/Ca ratio among parents but yielded better than IR 64 and ADT 45 which may be one of its characteristic to perform better despite stress condition. Lowest Ci/Ca (0.0) ratio was observed in CB13-900-C-2-27 which had lowest grain yield, but varied Ci/Ca ratio with varied grain yield was noticed among BILs. Sikuku *et al*. (2010) observed transpiration rate in NERICA rice varieties generally decreased with increase in soil water deficit. Results obtained from our study showed that mean of transpiration rate in BILs were lower than Parental mean. ADT 45 recorded highest transpiration rate while Apo and Anna recorded least transpiration rate among parents. Few BILs showed higher rate of transpiration under stress which revealed that several genotypes had acquired as they showed moderate grain yields but some of the BILs showed lesser transpiration rate but still were able to yield better which signifies lesser moisture loss and high carbon use efficiency under drought. This results agrees the reports of Swamy *et al.,* 2013 that the +QTL of BILs suggests transpiration advantage and yield advantages under drought are not due to architectural

Table 1
Mean Value Comparison of Physiological Traits with Grain Yield for Selected Individuals under Stress Condition

Genotypes	*PSR*	*STC*	*Ci*	*TR*	*Ci/Ca*	*RWC*	*OP*	*CC*	*LS*	*LR*	*LD*	*PE*	*Y/P*
IR64(p)	8.100	0.200	239.7	5.400	0.600	53.45	2.716	31.85	4.000	3.000	6.000	3.000	3.485
ADT45(p)	5.100	0.300	343.9	11.00	0.900	68.95	2.708	23.45	8.000	6.000	8.000	4.000	1.665
APO(p)	8.300	0.150	156.4	3.150	0.100	79.95	2.806	32.55	1.000	2.000	3.000	5.000	7.500
ANNA 4(c)	10.55	0.100	224.8	3.500	0.600	65.80	2.459	30.95	2.000	0.500	4.000	3.000	5.57
BILs													
CB13-900-C-2-14	7.450	0.100	267.6	3.700	0.700	64.90	2.500	26.25	5.000	8.000	8.000	4.000	4.255
CB13-900-C-2-17	9.800	0.600	296.2	7.550	0.800	62.65	2.399	40.90	1.000	2.000	3.000	3.000	13.46
CB13-900-C-2-23	15.15	0.200	269.7	5.050	0.700	69.40	2.169	32.75	1.000	0.000	1.000	2.000	27.35
CB13-900-C-2-25	12.10	0.200	286.8	5.100	0.700	66.30	1.944	35.75	1.000	0.000	2.000	3.000	13.77
CB13-900-C-2-27	7.900	0.100	150.3	2.200	0.000	77.95	2.506	27.70	6.000	7.000	7.000	5.000	1.000
CB13-900-C-2-37	14.15	0.100	127.2	2.700	0.300	79.90	2.401	29.90	1.000	0.000	2.000	3.000	9.865
CB13-900-C-3-5	7.300	0.150	281.5	4.350	0.800	64.30	2.788	25.75	5.000	5.000	5.000	5.000	6.880
CB13-900-C-8-1	7.400	0.200	302.8	5.000	0.800	65.55	2.539	34.30	4.000	8.000	7.000	5.000	5.630
CB13-900-C-8-15	8.750	0.100	241.8	3.650	0.650	67.50	2.381	31.25	4.000	6.000	4.000	2.000	13.04
CB13-900-C-8-16	10.90	0.300	317.1	7.200	0.800	66.10	2.462	33.45	2.000	4.000	4.000	2.000	8.580
CB13-900-C-8-18	10.35	0.150	191.9	3.900	0.700	63.55	2.454	31.00	5.000	6.000	4.000	2.000	9.565
CB13-900-C-238-1	7.400	0.100	268.6	3.700	0.700	56.50	2.654	31.25	5.000	6.000	7.000	4.000	6.010
CB13-900-C-238-2	10.00	0.200	306.1	7.150	0.800	68.05	2.406	37.50	4.000	1.000	3.000	2.000	16.02
CB13-900-C-238-3	12.75	0.200	255.9	4.650	0.650	90.65	2.669	32.50	1.000	0.000	2.000	1.000	18.12
CB13-901-C-38-2	11.30	0.100	103.3	2.400	0.300	72.10	2.457	32.60	2.000	0.000	2.000	2.000	14.95
CB13-901-C-38-3	12.30	0.100	148.5	2.450	0.350	70.30	2.491	31.10	3.000	2.000	4.000	3.000	11.03
CB13-901-C-238-1	8.900	0.100	192.3	2.400	0.500	68.75	2.495	38.00	1.000	6.000	4.000	1.000	8.370
CB13-902-C-238-1	7.850	0.150	238.3	4.850	0.600	82.30	2.739	25.70	5.000	7.000	5.000	3.000	11.80
Mean(p)	8.013	0.188	241.20	5.763	0.550	67.04	2.672	29.70	3.750	2.875	5.250	3.750	4.555
Mean(BILs)	10.10	0.175	235.88	4.333	0.603	69.82	2.470	32.09	3.111	3.778	4.111	2.889	10.66
Min(BIls)	7.300	0.100	103.30	2.200	0.000	56.50	1.944	25.70	1.000	0.000	1.000	1.000	0.710
Max(BIls)	15.15	0.600	317.10	7.550	0.800	90.65	2.788	40.90	6.000	8.000	8.000	5.00	27.35

PSR photosynthetic rate; *STC* stomatal conductance; *Ci* inter cellular carbon concentration; *TR* transpiration rate; *Ci/Ca* rate of photosynthesis; *RWC* relative water content; *CC* chlorophyll content; *LS* leaf senescence; *LR* leaf rolling; *LD* leaf drying; *PE* panicle exertion; *Y/P* yield per plant

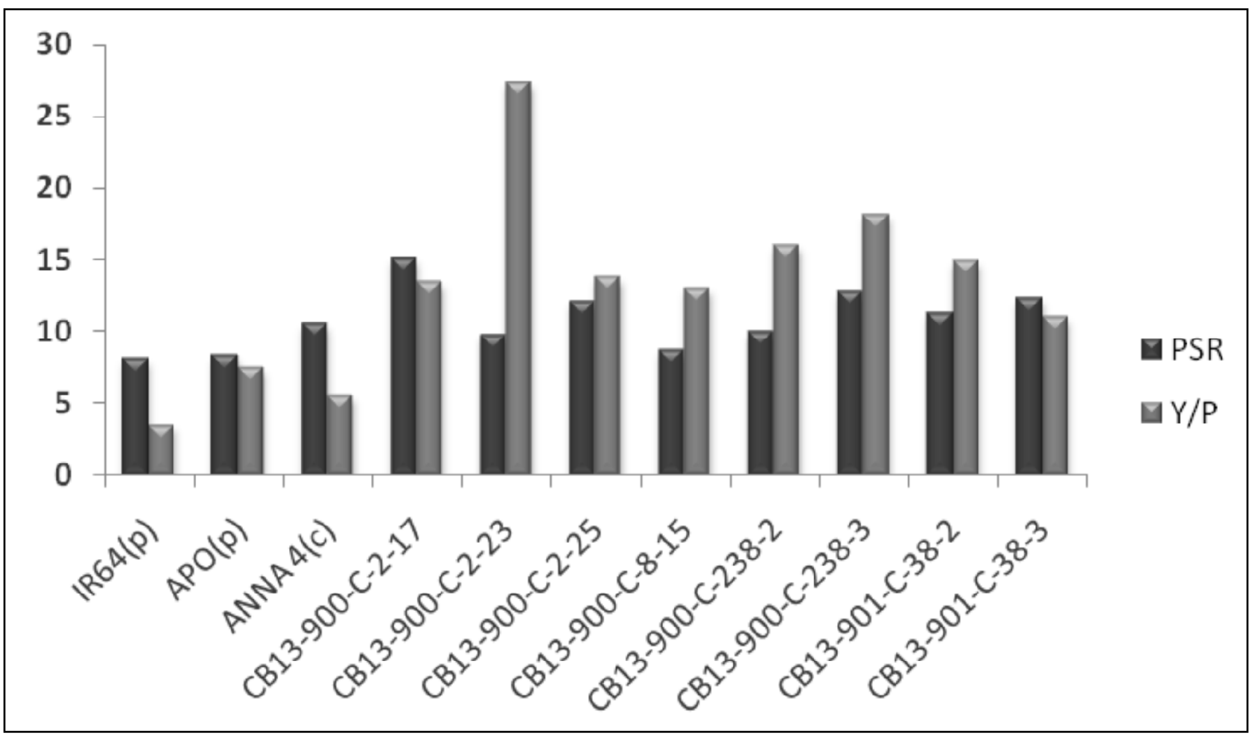

Figure 1: Effect of photosynthetic rate on grain yield under stress

or allometric differences in plant growth but due to presence of QTLs. Relative water content is the appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit while water potential as an estimate of plant water status is useful in dealing with water transport in the soil-plant-atmospheric continum. Teulat *et al*. (2003) reported that relative water content was a relevant screening tool for drought resistance in cereals, as it was a good indicator of plant water status. In this study 90.65% of relative water content was recorded by BIL with 3 QTL CB13-900-C-238-3 which also recorded moderate to high values in other physiological parameters , such similar results was reported by Kumar and Kujun (2003) that maintenance of high water status under drought plays a major role in stabilizing the various plant responses and yield. All the BILs recorded higher RWC compared to IR 64 and ADT 45, whereas Apo had higher RWC compared to other parents and check. Most of the BILs and Anna 4 recorded moderate RWC under severe stress condition. Osmotic potential among BILs showed lesser value compared to parental mean value. Highest osmotic potential was observed in Apo among parental lines, IR 64 and ADT 45 recorded higher values. Whereas, lowest value was recorded by Anna 4 which yielded better than parents, except two BILs all others recorded lower values compared to parents and comparatively recorded higher grain yields also. Least osmotic potential was noticed among BILs which was recorded by CB13-900-C-2-25 (-1.944) which possessed single QTL *DTY* 2.2 which recorded 13.77 grams of grain yield. BIL possessing single QTL DTY3.1 recorded highest osmotic potential but had lesser grain yield which signifies the differential action of DTY2.2 and DTY 3.1.Higher the Osmotic potential lower or moderate grain yield was recorded, which signifies tolerance at the cost of grain yield. But higher grain yielder recorded moderate and lower levels of osmotic potential. The region on chromosome 2 in which q*DTY*2.2 was detected has been reported previously to have an effect on drought-related traits other than GY, including drought tolerance index, canopy temperature, osmotic adjustment, and leaf water content (Verulkar *et al.,* 2010). Mallikarjuna Swamy *et al.,* 2013 opines that the clustering of a number of physiological traits in the same region suggests its importance for GY under severe drought stress. Chlorophyll content is an indicator of photosynthetic rate and it is an important measurement that can indicate the photosynthetic efficiency of plants system. ADT 45 and IR 64 recorded lesser chlorophyll content than other parents, checks and BILs. Among the BILs higher chlorophyll content was noticed among better grain yielders; moderate values were recorded by BILs, Apo and Anna 4.

Panicle exertion is an important criterion to yield. Boonjung and Fukai (1996) reported that poor panicle exsertion was the main cause for spikelet sterility which in turn reduces the yield. In this study, Apo and Anna 4 showed moderate exertion while several BILs had high panicle exsertion coupled with higher yield under drought which agrees with reports of Subashri *et al*. (2008) which indicated the importance of panicle exsertion for improving the grain yield under drought prone environment. Highest and lowest panicle exertion was seen among BILs and also showed corresponding increase and decrease in grain yield levels respectively. The critical period of rice during drought coincides with panicle development to anthesis stage. Reduction in leaf water potential (LWP) at anthesis may cause poor panicle exsertion and increase the sterile spikelets during stress condition (Ekanayake *et al*., 1989). Senescence is an important trait with response to productivity under drought since the carbohydrate remobilization triggered by this trait is paramount in grain filling under drought. In this study the population exhibited varied expression for leaf senescence but maximum number of BILs had lower leaf senescence indicating tolerance by keeping higher photosynthesis rate under stress condition. Apo showed least leaf senescence followed by Anna 4, whereas ADT 45 showed higher leaf senescence followed by IR 64. Yang *et al*. (2001) reported that early leaf senescence induced by water deficit during grain filling can enhance the remobilization of stored assimilates and accelerate grain filling of rice. Kumar *et al*. (2006) also reported the same result in their study under stress condition. Leaf rolling is an expression of wilting in rice and it has received much attention in the selection process. Price and Courtois (1999) considered that triggering of leaf rolling was an indication of a plant suffering of moisture stress and suggested to select against its early manifestation. In this study, good grain yielders recorded zero scoring for leaf rolling and among parents ADT 45 followed by IR 64 expressed slightly higher score of leaf rolling and several BILs surpassed the check Anna 4 by registering no leaf rolling thus indicating tolerance to moisture stress. Singh and Mackill (1991) reported that enhanced ability to roll leaves conferred yield advantage under drought conditions. Genotypes expressing relatively delayed leaf rolling might have relatively better access to soil water or better osmotic adjustment (Blum 1988). Similarly leaf drying scoring was less among high grain yielders and high among less grain yielders. ADT 45 followed by IR 64 showed high dryness indicating sensitiveness to severe stress conditions while, QTL donor Apo and check Anna 4 recorded less leaf drying. BIL with three QTL [DTY (2.2+3.1+8.1)] in background of ADT 45 genome performed with moderate values of photosynthetic rate and relative water content and other physiological traits, the BIL also recorded moderate grain yield levels and overall performance of the BIL was better compared to ADT45 which shows significance of introgressed QTLs. The results of the study shows the significant level of trait expression under severe stress, and also confirms that parental lines without yield under stress QTLs were worst performers and showed lesser values when compared to BILs, however Anna 4 showed moderate values but still it was a poor yielder when compared to most of the BILs. BILs with QTL 2.2 recorded higher photosynthetic rate where as DTY 3.1 possessing line showed higher osmotic potential, but the BIL with all the three QTLs [DTY (2.2+3.1+8.1)] recorded highest RWC, higher photosynthetic rate, and performed good for all other physiological traits which signifies the combination effect of the three QTL on physiological traits as well as grain yield.

CORRELATION STUDIES

Correlation studies revealed significant association of different physiological traits with grain yield under severe moisture stress conditions (Table 2). Photosynthetic rate had significant positive correlations with chlorophyll content grain yield per plant and significant negative correlations with osmotic potential, leaf senescence, leaf rolling, and leaf drying and also with panicle exertion. Significant correlation was observed between ci and conductance. Transpiration rate too recorded significant values while correlating with conductance and Ci. Ci/Ca ratio also had significant correlations with conductance, Ci and transpiration rate. The similar kind of results were reported by earlier reports as well (Bidinger *et al.*, 1999; Pantuwan *et al.*, 2002; Lafitte *et al.*, 2004; Lanceras *et al.*, 2004). Relative water content recorded negative correlations with conductance, transpiration rate, leaf drying, leaf rolling, and leaf senescence as all these physiological functions leads to water loss in plant system. Traits like leaf water potential, leaf rolling, leaf drying, canopy temperature and delay in flowering time can reflect the internal water status under water stress and these traits can be considered as integrative traits to identify drought resistant genotypes.

RWC showed positive correlation with transpiration rate and photosynthetic rate showed positive correlation with stomatal conductance and single plant yield and the same kind of result was reported earlier by Shen (1980) and Chen *et al.*, (1995). All the BILs recorded higher RWC compared to IR 64 and ADT 45, whereas Apo had higher RWC compared to other parents and check. Most of the BILs and Anna 4 recorded moderate RWC under severe stress condition. Osmotic potential had significant positive

Table 2
Correlation Coefficients among Traits under Stress Condition

Traits	*PSR*	*COND*	*Ci*	*TR*	*Ci/Ca*	*RWC*	*OP*	*CC*	*LS*	*LR*	*LD*	*PE*	*Y/P*
PSR	1.000	0.329	-0.269	-0.143	-0.124	0.222	-0.500*	0.577**	-0.739**	-0.706**	-0.748**	-0.491*	0.568**
COND		1.000	0.548**	0.726**	0.468**	-0.181	-0.092	0.420	-0.141	-0.135	-0.099	-0.043	0.138
Ci			1.000	0.806**	0.886**	-0.373	-0.046	0.057	0.263	0.217	0.286	0.056	0.016
TR				1.000	0.705**	-0.216	0.040	0.009	0.292	0.028	0.180	-0.004	-0.025
Ci/Ca					1.000	-0.476*	-0.104	0.086	0.212	0.158	0.157	-0.181	0.147
RWC						1.000	0.138	-0.179	-0.245	-0.229	-0.358	-0.129	0.165
OP							1.000	-0.466*	0.428*	0.393	0.489**	0.375	-0.578**
CC								1.000	-0.685**	-0.414	-0.533*	-0.445*	0.504*
LS									1.000	0.715**	0.822**	0.460*	-0.645**
LR										1.000	0.830**	0.405	-0.707**
LD											1.000	0.598**	-0.833**
PE												1.000	-0.615**
Y/P													1.000

PSR photosynthetic rate; *STC* stomatal conductance; *Ci* inter cellular carbon concentration; *TR* transpiration rate; *Ci/Ca* rate of photosynthesis; *RWC* relative water content; *CC* chlorophyll content; *LS* leaf senescence; *LR* leaf rolling; *LD* leaf drying; *PE* panicle exertion; *Y/P* yield per plant correlation with leaf senescence and leaf drying but significant negative correlation with grain yield per plant. Higher the osmotic potential higher the stress experienced by plants. Chlorophyll content had highly negative correlations with leaf senescence, leaf drying and panicle exertion but, positively correlated with grain yield per plant. Leaf senescence, drying and rolling had significant mutual positive correlations and all the three and panicle exertion had significant negative correlation with grain yield per plant. Among major physiological traits except photosynthetic rate, osmotic potential only showed significant correlations with grain yield and traits like Ci/Ca ratio, RWC, Ci varied among BILs and showed no significant correlations with grain yield values.

In our study it was concluded that the QTL introgressed BILs expressed varying levels of physiological parameters and exhibited higher response than their susceptible parents which indicates the significant effect of QTLs for yield under severe stress. Three QTL line possessing *DTY* (2.2+3.1+8.1) showed higher grain yield, highest relative water content and optimal values among other traits, which directs us to assume that yield under stress QTL regions possess the favorable genes for drought tolerance. However some BILs recorded moderate values among the physiological traits but were good yielders and vice versa showing the complexity of drought tolerance through traits expression. Detailed studies in this regard can better explain the function and relation of QTLs (yield under stress) with physiological traits.

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